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Evaluating the Impact of Spent Mushroom Substrate on Growth and Yield of Okra (Abelmoschus esculentus (L.) Moench)

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Abstract
The utilization of natural organic wastes is a significant environmentally safe application in crop production. Consequently, this study investigates the effect of spent mushroom substrate on the growth and yield of okra. Physico-chemical analysis was done on the soil and the pH level of the varied treatments was analyzed as well. The treatments of the SMS consisted of 0%, 5%, 10%, 25% and 50%. The study set out in a randomized complete block design (CRD) with four replications per treatment. The effect of the spent mushroom substrate showed non-significant differences for most growth and yield-related traits of okra, including germination time, number of leaves, number of branches, stem diameter, number of pod, weight of pod, length of pod and width of pod as compared with the control treatment. Significant differences were recorded for plant height and leaf area. Among all the treatments, the highest plant height (31.08 cm) resulted in the 0% treatment while the minimum plant height (14.2 cm) came from the 10% treatment. 0% has the highest leaf area (130.75 cm^2) while 50% has the minimum (42.0 cm^2). SMS prolonged the life span of the plant as compared with the control.

Keywords: Organic wastes, spent mushrooms substrate, Okra, Physico-chemical analysis

Introduction
Vegetables are cultivated in many part of the world and they constitute the major source of diets to humans (Silva Dias, 2010). The attention of the vegetable international market is on vegetables that have marginal processing and are also consumed fresh (Naujokat, 2004). Okra [*Abelmoschus esculentus* (L.) Moench] is a nutritious and an economically useful vegetable crop which is grown in the tropical and warmer regions of the world (Patil *et al.*, 2015). The production rate of Okra in the world stands at 9.6 million tonnes per year whereas more than 1.82 million tonnes is produced in (FAOSTAT, 2008).

Okra belongs to the family Malvaceae. It is an annual herb and indigenous to Africa. It is cultivated widely in Western and Central Africa (Komolafe *et al.*, 2021; Singh *et al.*, 2014). It is mainly cultivated for its immature fruits which are cooked and eaten in countries like Sudan, Egypt and Nigeria (Olaniyi *et al.*, 2010). Okra is one of the most recognized and utilized species in the family Malvaceae (Naveed *et al.*, 2009). It contains significant amount of dietary fibers, minerals, vitamins (A, B and C), antioxidants, folate, protein, oil and unsaturated fatty acids. Mucilage from okra can be used as a food additive while the mature fruit and stems are utilized in the paper industries (Das, *et al.*, 2019; Badrie, 2016).

Okra grows well in varied soils, but it performs optimally in well- drained sandy and clay loam soils, especially the ones adequate with organic matter. According to Iyagba *et al.* (2012), okra grows best on loams and sandy loams, but will produce good yields on heavier soils. The search for ecologically supporting plant-based fertilizers with organic residues has heightened the demand for SMS as against the usage of field inventories that are hazardous to plant, man and the ecosystem (Nmom *et al.*, 2020).

Composting is a natural process by which organic materials such as leaves and residual wastes are converted into useful products to be amended with the soil for adequate supplies of nutrients to the plant (Karbout *et al.* 2021). Composting is also a biological process by which microbes transform organic materials into useful end products, for application as soil conditioners and organic fertilizers (Sánchez *et al*., 2017; Buchanan and Gliessman, 1991). Recycling foodstuff and other organic waste into compost provides environmental benefits which comprises improving soil health, reducing greenhouse gas emissions, recycling nutrients, and mitigating the impact of droughts. Composting is a sustainable approach to recycle organic wastes into organic amenders that are as significant as the potting soil media (Petrillo *et al.*, 2020; Barthod *et al.*, 2018).

Mushroom compost can be derived from chopped hay, poultry manure, gypsum, and water. After harvesting the mushrooms, the spent compost or spent mushroom substrate can improve organic farming by enhancing soil water infiltration, water holding capacity, permeability, and aeration. Nonetheless, the application of compost as a basal substrate can pose challenges like high salt content (Castillo *et al.*, 2004), unsuitable physical properties (Ribeiro *et al.*, 1999), and variable quality and composition (Hicklenton *et al.*, 2001). The spent mushroom substrate holds significant amount of salt and unstable organic matter which needs about two years before its usage. This measure aids organic dissolved substances to leach out and decompose as organic substances. The mushroom compost used contains nitrogen (12%), phosphorus (0.2%), and potassium (1.3%). With 18 months of aging, the phosphorus and nitrogen do not change, but potassium can decrease (Uzun, 2004).

Various types of materials can be utilized as seed planting media (Moldes *et al.*, 2007). The major characteristics needed for a growth media include accessibility, affordability, and abundance (Demir *et al.*, 2010). The cost of inorganic fertilizers is not affordable to local farmers in developing countries like Nigeria. Due to poor farming practices, many agricultural lands have been depleted of its nutrients. There is a need to look for an alternative source of organic fertilizers which will boost the growth and production of vegetables by the local farmers. Therefore, it was the objective of the present studies to evaluate the impact of spent mushroom substrate on the growth and the yield of Okra.

Materials and Methods

Sample collection: The seeds of '40 days' cultivar of *Abelmoschus esculentus* were collected from the Agricultural Development Project (ADP) office in Anyigba, Kogi State, Nigeria. The SMS used for the cultivation of *Pleurotus tuberigium* were collected from the mushroom section of the Department of Plant Science and Biotechnology, Faculty of Natural Sciences, Prince Abubakar Audu

University (PAAU), Anyigba. The university is located on coordinate 7.4934°N and7.1736°E. It has an average altitude of 385 m.a.s.l. The average mean rainfall and temperature of Anyigba is 1250 mm and 25°C. it falls within the tropical wet and dry (Aw) climatic region and the derived savanna. The top soil used for this study was collected at the Research Garden of the Department of Biological Sciences, Faculty of Natural Science, PAAU, Anyigba

Preparation of the growth media: The spent mushroom substrates were weighed in different quantities. Four different levels [5% (200 g), 10% (400 g), 25% (1000 g) and 50% (2000 g) w/w] of the SMS was added to the top soil to give a weight of 4000 g in separate buckets. Each bucket was mixed thoroughly and placed in 35 cm X 40 cm polyethylene bag. Five treatments of 0%, 5%, 10%, 25% and 50% were each replicated four times to give a total of twenty polyethylene bags. Each treatment was arranged in a Completely Randomized Design.

Chemical analysis: The Soil samples collected was analyzed for soil properties and pH, as well as macro- and micronutrients (Table 1) at the laboratory of the Department of Geology, Faculty of Sciences, PAAU, Anyigba using standard procedures. Thee mineral composition of the soil was as follows: 9.10 ppm (Ca), 4.3 ppm (K), 15.10 ppm (Mg), 66.67 ppm (N), 12.0 ppm (Na), and 2.91 ppm (P). The pH of the amended soil in the various treatments was also analyzed to know if it is within the range for Okra's optimal performance (Table 2).

Table 1: Physico-chemical Properties of the Soil before Amendment

Soil Parameter	Quantity
Field capacity (mm)	111.08
Permanent wilting (mm)	104.31
Availability of water (%)	6.77
Sand (%)	27.78
Silt (%)	4.17
Clay (%)	68.05
pH	5.79
Organic Matter (PPM)	17.90
Nitrogen (PPM)	66.67
Phosphorus (PPM)	2.91
Sodium (PPM)	12.0
Potassium (PPM)	4.30
Calcium (PPM)	9.10
Magnesium	15.10

Table 2: pH of the Soil after amendment

Percentage of Treatment (SMS)	pH
0	5.79
5	6.1
10	6.21
25	6.53
50	6.67

Seed planting: After the application of SMS, the set-up was left for two days on the experimental plot before planting. Three seeds were sown per hole at a depth of 2 cm on the 9th of August, 2023. After germination, the seedlings were thinned down to one plant per stand to avoid competition.

Maintenance: Weeds were removed from each bag as soon as they emerge to avoid competition with the okra plants. The plants were watered every 2 days after the termination of the rainy season up until the end of the research. Leaf beetles were the major pests that attacked the okra plant in the field. This was controlled by dusting the plant with a systemic insecticide called pif-paf.

Studied parameters: Growth and yield parameters were studied for this work. The growth parameters measured were germination rate, height of plant, number of leaves per plant, leaf area per plant (cm^2), number of branches per plant, stem diameter per plant (cm) and they were taken 5 Weeks After Planting (WAP). The yield parameters measured were number of pods, weight of pod (g), length of pod (cm), and width of pod (cm). Harvesting of pod started on the 9th WAP and ended on the 18th WAP. All measurements were done according to the method of Akinyele and Adigun (2006).

Analysis of data: The data generated from this study was subjected to analysis of variance (ANOVA). Test of significance were determined by Duncan's multiple range test at 0.5% level of probability ($p \leq 0.05$).

Results

Growth rate at 5 WAP

At the same age, the height of the plants produced showed that 50% had the slowest growth rate while the control has the fastest (Fig. 1).

Figure 1: Okra grown at 5 WAP in varying levels of SMS (A = 0%; B = 5%; C= 10%; D = 25%; E = 50%).

Germination rate

The application of various levels of the SMS did not display significant differences in the germination rate (Fig. 2). 0%, 5% and 50% showed the highest germination rate while 10% showed the least germination rate.

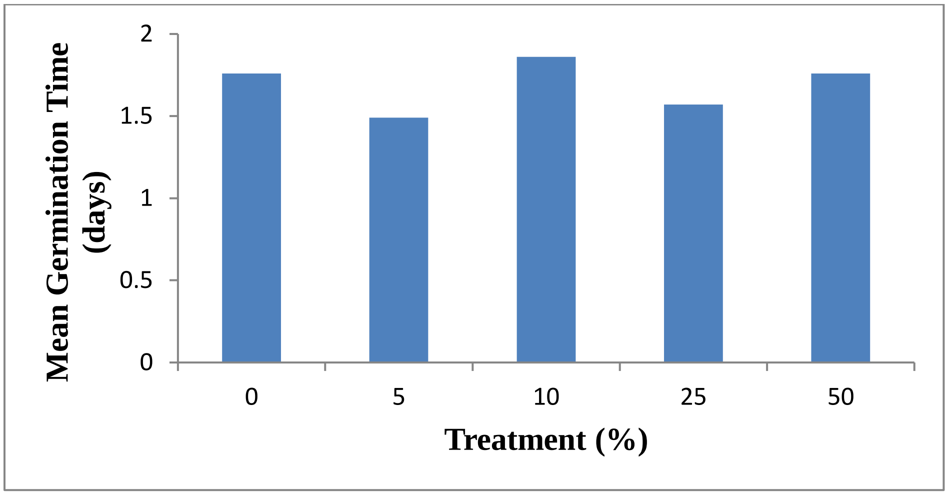

Figure 2: Effect of spent mushroom substrate (SMS) on mean germination time of okra plant. Bars with the same alphabet (s) are not significantly different (DMRT $p<0.05$).

Number of leaves

The application of various levels of the SMS did not display significant differences in the number of leaves (Fig. 3). Treatment 0% showed the highest number of leaves (5.0) while 10% showed the least number of leaves (3.0).

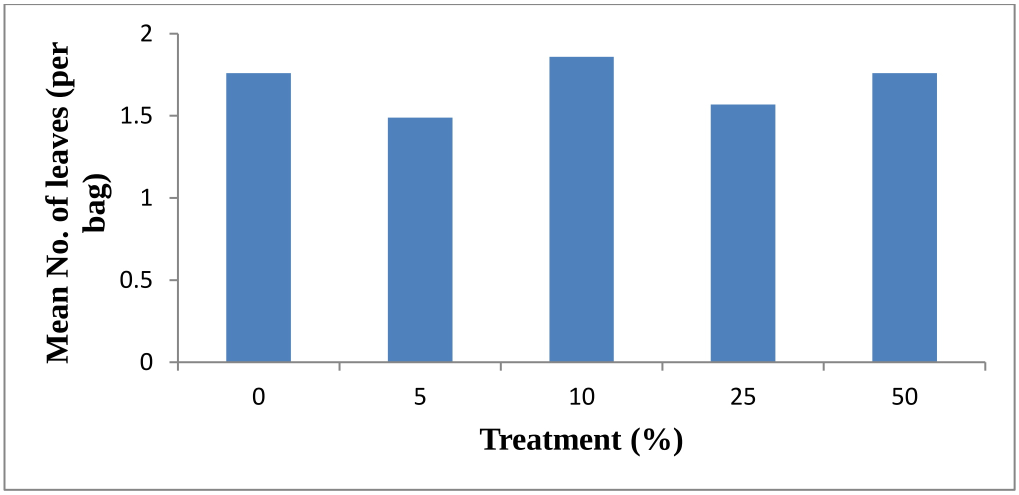

Figure 3: Effect of spent mushroom substrate (SMS) on mean number of leaves of okra plant. Bars with the same alphabet (s) are not significantly different (DMRT $p<0.05$).

Number of Branches

The application of various levels of the SMS did not display significant differences in the number of branches (Fig. 4). Treatment 0% showed the highest number of branches (5.75) while 10% showed the least number of leave (3.25).

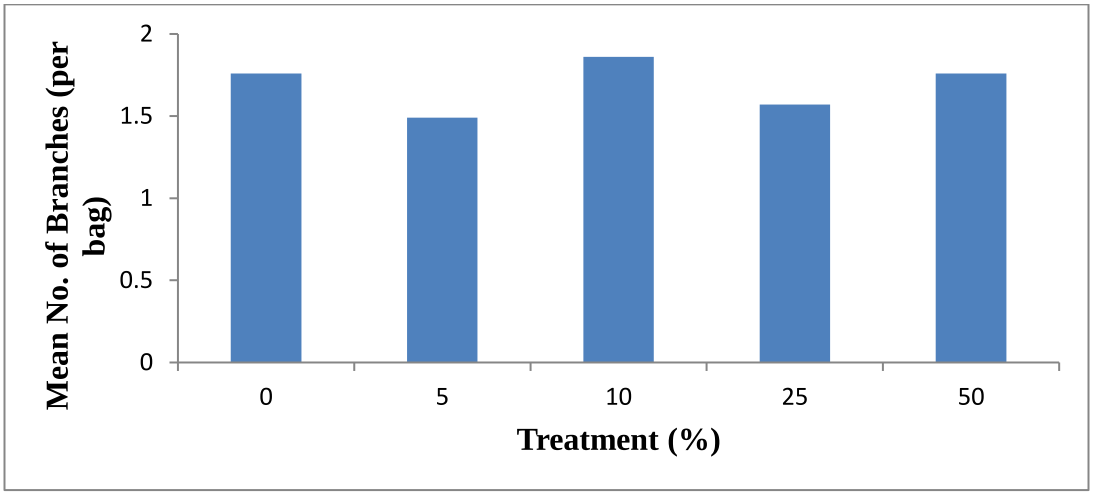

Figure 4: Effect of spent mushroom substrate (SMS) on mean number of branches of okra plant. Bars with the same alphabet (s) are not significantly different (DMRT $p<0.05$).

Height of Plant

The application of various levels of the SMS displayed significant differences in the plant height (Fig. 5). The maximum plant height showed 31.08 cm, as observed in the treatment 0%. However, the minimum plant height (14.2 cm) came from the treatment 10%.

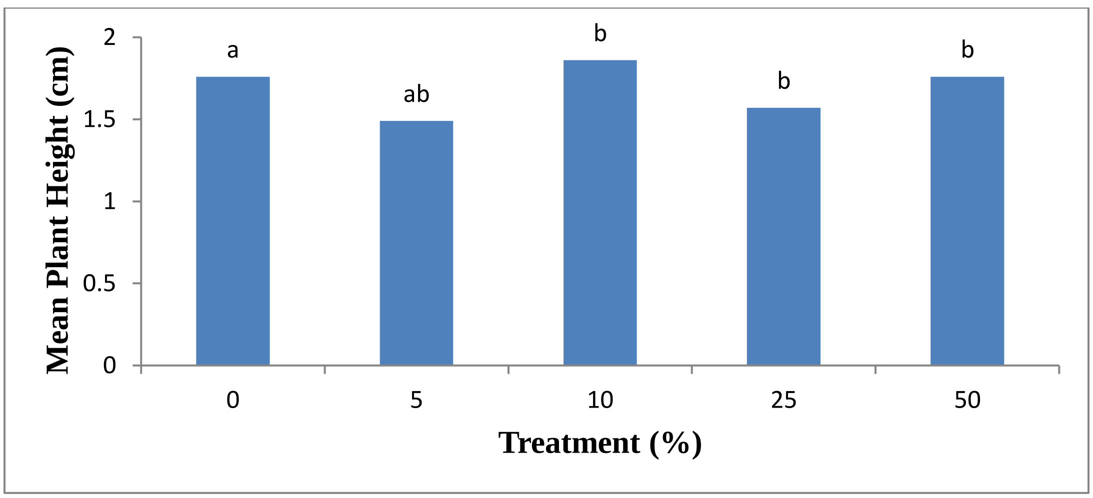

Figure 5: Effect of spent mushroom substrate (SMS) on mean plant height of okra plant. Bars with the same alphabet (s) are not significantly different (DMRT $p<0.05$).

Stem Diameter

The application of various levels of the SMS did not display significant differences in the stem diameter (Fig. 6). Treatment 0% showed the highest stem diameter (0.61 cm) while 10% showed the least number of leave (0.35 cm).

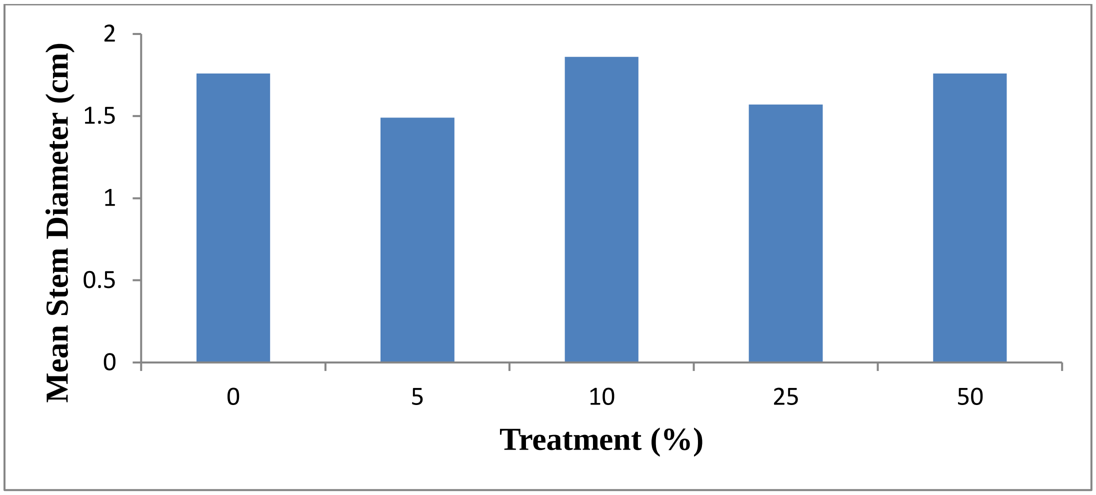

Figure 6: Effect of spent mushroom substrate (SMS) on mean stem diameter of okra plant. Bars with the same alphabet (s) are not significantly different (DMRT $p<0.05$).

Leaf Area

The application of various levels of the SMS displayed significant differences in the leaf area (Fig. 7). The maximum leaf area showed 130.75 cm^2, as observed in the treatment 0%. However, the minimum leaf area (42.0 cm^2) came from the treatment 50%.

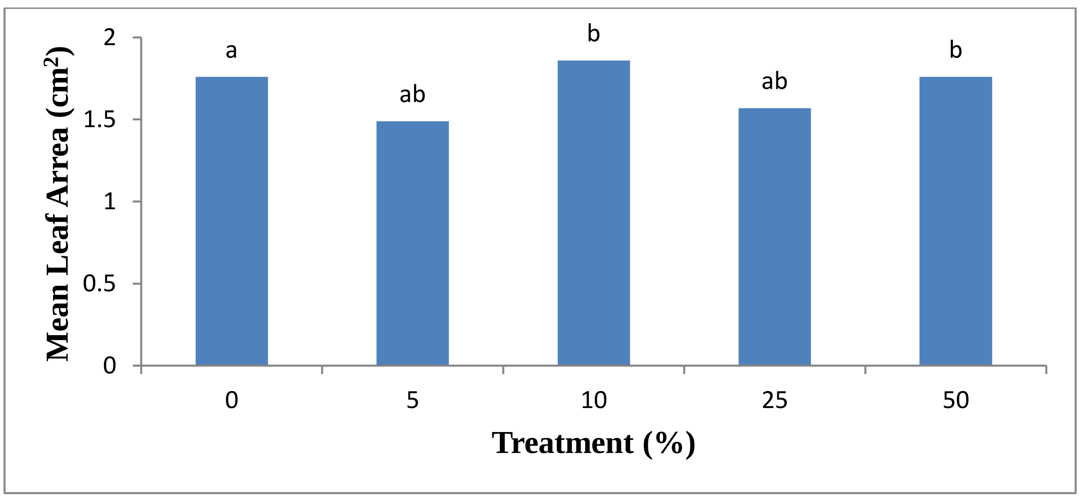

Figure 7: Effect of spent mushroom substrate (SMS) on mean leaf area of okra plant. Bars with the same alphabet (s) are not significantly different (DMRT $p<0.05$).

Number of pod

The application of various levels of the SMS did not display significant differences in the number of pod (Fig. 8). Treatment 0% showed the highest number of pod (4.0) while 50% showed the least number of leave (2.25).

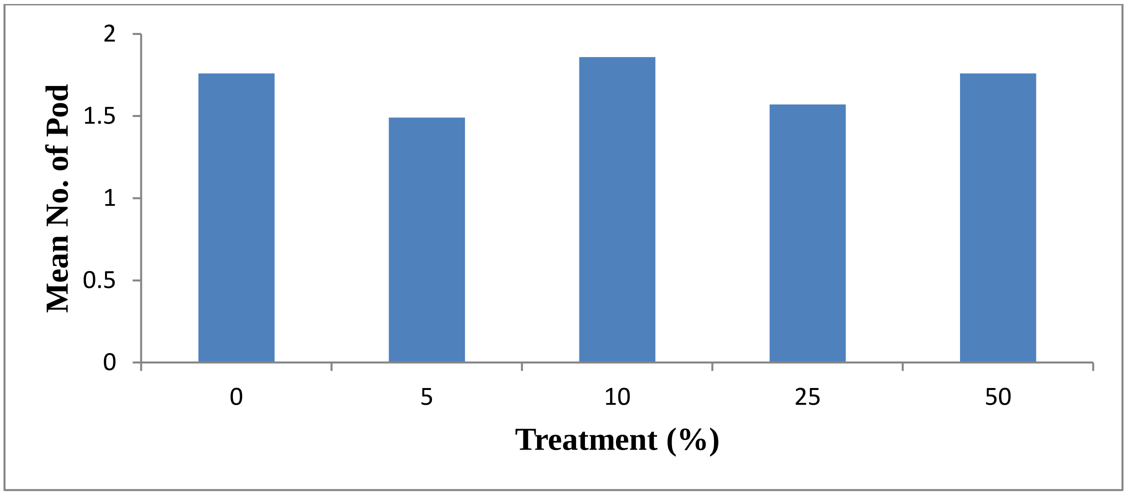

Figure 8: Effect of spent mushroom substrate (SMS) on mean number of pods of okra plant. Bars with the same alphabet (s) are not significantly different (DMRT $p<0.05$).

Weight of pod

The application of various levels of the SMS did not display significant differences in the weight of pod (Fig. 9). Treatment 0% showed the highest weight of pod (3.72) while 5% showed the least number of leave (1.84).

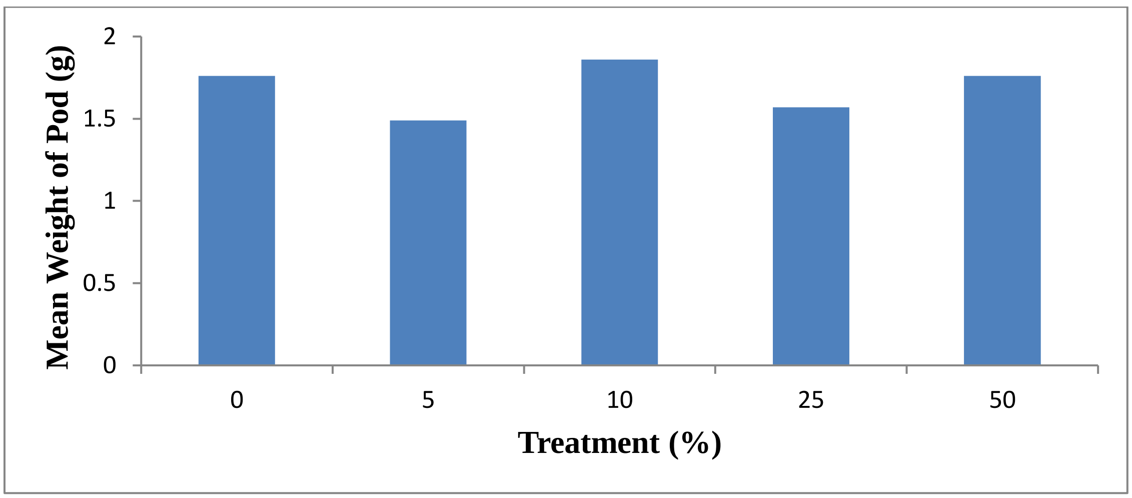

Figure 9: Effect of spent mushroom substrate (SMS) on mean weight of pod of okra plant. Bars with the same alphabet (s) are not significantly different (DMRT $p<0.05$).

Length of pod

The application of various levels of the SMS did not display significant differences in the length of pod (Fig. 10). Treatment 0% showed the highest length of pod (3.83) while 5% showed the least number of leave (2.75).

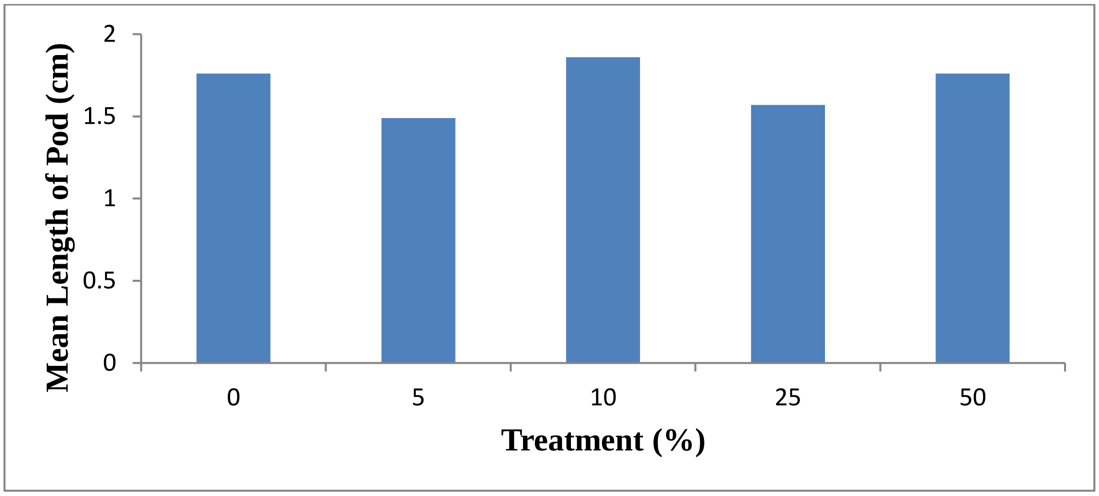

Figure 10: Effect of spent mushroom substrate (SMS) on mean length of pod of okra plant. Bars with the same alphabet (s) are not significantly different (DMRT $p<0.05$).

Width of pod

The application of various levels of the SMS did not display significant differences in the width of pod (Fig. 11). Treatment 10% showed the highest width of pod (1.86 cm) while 5% showed the least number of leave (1.49).

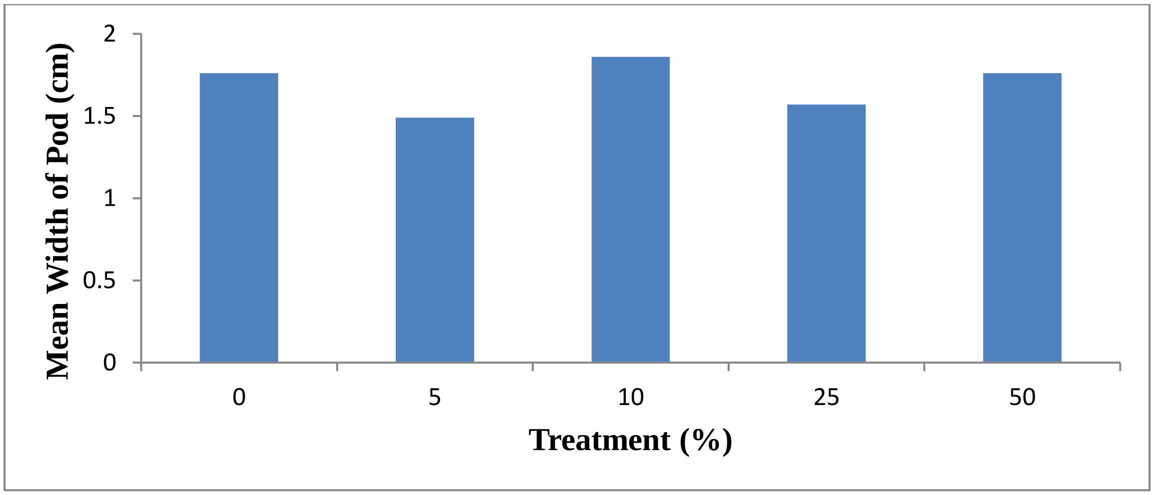

Figure 11: Effect of spent mushroom substrate (SMS) on mean width of pod of okra plant. Bars with the same alphabet (s) are not significantly different (DMRT $p<0.05$).

Discussion

The pH of the soil of the field experiment is slightly acidic (Table 1). Okra can tolerate slightly acidic medium between the pH range of 4.5 and 7 (Umeri *et al.*, 2003). A progressive decrease in height was observed from treatment 0% to treatment 50% at 5 WAP (Fig. 1). This indicates that the addition of SMS to the soil may have affected the rate of nutrient uptake by the okra plant which translated into the poor morphological performance of the plant. Bustamante *et al*. (2008) and Grigatti *et al*. (2007) reported that the maximum plant growth responses and maximum yields have usually been recorded when composts make up only a relatively small percentage of the volume of a greenhouse container medium mixture.

The soil used for this study is rich in clay, organic matter, nitrogen and slightly acidic (Table 1). These soil conditions agreed with the soil recommended by Osekita *et al.*, (2008) for okra production. There was progressive increase in the pH of the soil with increase in the percentage of SMS from 5.79 (0%) to 6.67 (50%) (Table 2). Yu *et al.* (2021) corroborated the capacity of SMS to increase the pH of the soil. By implication, the amount of SMS used in crop production will depend on the pH requirement of such crop. This finding is contrary to the studies by Paredes *et al.*, (2016). They reported that the addition of spent mushroom substrate does not alter the soil pH nor does its incorporation produce significant changes in the soil physico-chemical properties.

Six out of the ten (10) attributes studied in Table 3 were growth (vegetative) while the other four (4) were the yield attributes. Eight (8) out of the ten (10) studied did not show significant differences among the different levels of SMS. These eight (8) attributes are germination time, number of leaves, number of branches, plant diameter, number of pods, weight of pods, length of pods and width of pods. This is an indication that they are stable attributes and that varying the level of SMS in a way did not affect their performance. Hence, supplementing the soil with SMS will not affect the performance of okra when emphasis is laid on the vegetative growth and yield attributes tested. This finding is in consonance with the report of Alege *et al.* (2009) and Vavrina *et al.* (1996) that the number of pods, length of pods, number of branches and the number of leaves did not vary with the application of organic and inorganic fertilizers.

The two (2) attributes that showed significant difference are plant height and leaf area (Fig. 5 and 7). This further indicates that these attributes vary with the application of SMS. Hence they are not stable and their performance is affected by SMS. This is also corroborated by the findings of Alege *et al.*, (2009) and Vavrina *et al.* (1996) that plant height and leaf area are not stable attributes in okra as they vary with nutrient status of the soil. Although, attributes like number of leaves, stem diameter, pod diameter also showed significant differences to the nutrient status of the soil which were observed not to be significant to SMS in this study.

The addition of SMS did not actually improve the performance of okra (Fig. 2-11). This revealed that the addition of SMS may not play significant role in nutrient uptake in okra plants. Romaine and Holcomb (2001) reported that garden crops or vegetables are sensitive to high salt which could affect their performance. It could well mean that the negative impact was as a result of ammonia nitrogen which had not undergone microbial conversion by composting to nitrates (Chonver *et al.*, 2001). However, the remarkable effect of SMS in the production of okra is that it prolonged the longevity of the plant as compared with the control. It shows that SMS retain much more moisture than the control. This aligns with the findings of Lopex-Castro *et al.* (2008) that spent oyster mushroom substrate harbors moisture which sustains the growth of plants.

Conclusion

This study revealed that SMS did not significantly increase the vegetative growth and yield of okra plants. Compared with the control, the application of SMS impacted the plant height and the leaf area. The present findings authenticated that spent mushroom substrate enhanced the life span of the plant. SMS can be used for mulching since it enables retention of moisture within the soil.

Recommendation

Despite the fact that application and use of spent mushroom substrate in cultivation of Okra has been highly recommended, its application in this studies has negatively affected the performance of Okra plant. In addition to allowing the spent mushroom substrate to pass through the process of weathering, it would be interesting to consider for future studies, the analysis of the physico-chemical properties of the spent mushroom substrate.

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